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Overview of application and navigation technology of epidemic prevention and control robot

Xianglin Wang, Yongxiang Jiang, Zhuo Xu, Yishui Liu, Yang Liu, Mincong Liang, Yuzhi Guo

Tianjin University of Technology and Education, Tianjin, China

Abstract: Facing the grim COVID-19, efficient and less contact has become the key to epidemic prevention and control, so robots are gradually becoming the only choice for human epidemic prevention and control. This paper discusses the navigation technology of mobile robots such as distribution and patrol, and focuses on the visual navigation technology, one of the navigation technologies. Finally, in view of the fact that visual navigation technology can better meet the functional requirements of epidemic prevention and control robots, the future research directions in this field are prospected.

Keywords: Epidemic prevention and control, navigation.

1. INTRODUCTION

In the process of fighting the COVID-19 epidemic, the whole nation is united. Medical personnel and epidemic prevention personnel are on the front line, and the whole people actively respond to national policies and actively cooperate with epidemic prevention. Robots also play a role in the fight against the epidemic because of their high efficiency and less contact. Since the outbreak of the epidemic, various robots have been used in different epidemic prevention and control scenarios, such as information collection, logistics and transportation and medical services. Their participation makes the epidemic prevention work more efficient and the safety of medical personnel and people better guaranteed.

Most robots are mobile robots in the army of new coronal epidemic prevention and control robots, and navigation technology is one of the core technologies of mobile robots. It refers to the autonomous movement of mobile robots towards targets in an obstacle environment by sensing environmental information and their own state through sensors. At present, the main navigation methods of mobile robot include : magnetic navigation, inertial navigation and visual navigation. Among them, visual navigation captures the image information of obstacles and landmarks by camera, and then detects and identifies the image information to achieve navigation. It has the advantages of wide signal detection range and complete information acquisition.

This paper introduces the navigation technology of mobile robots such as distribution and patrol, and focuses on the visual navigation technology. Finally, the development trend and prospect of visual navigation technology are introduced.

2. OVERVIEW OF NAVIGATION TECHNOLOGY FOR MOBILE ROBOT

2.1 Magnetic navigation

Magnetic navigation is widely used in robot autonomous navigation system because of its advantages of convenient maintenance, free from light changes and weather conditions. At present, magnetic navigation is mainly realized based on magnetic line of force, magnetic tape or magnetic nail medium. The magnetic line of force navigation needs to embed the enameled wire under the road in advance and provide it with a DC square wave power supply of 20 kHz to conduct robot navigation through the magnetic field generated by the enameled wire. This navigation mode has great damage to the road surface and troublesome construction, and once the enameled wire is damaged, it is easy to cause the paralysis of the entire navigation line. Although the magnetic tape navigation has no damage to the ground, the magnetic tape above the ground is easy to be rolled by the vehicle, which needs frequent replacement and late maintenance. The magnetic nail navigation only needs to embed the magnetic nail in advance on the road surface, which can complete the laying of the navigation path. It has the advantages of small construction difficulty, low cost, easy to change and expand the path.

Yuan Lisong[1]proposed a magnetic nail navigation method for automatic guided vehicle (AGV) in automated terminal, but it needs pose estimation to complete navigation and positioning, and the error is large.

Zhu Gang[2]proposed a magnetic nail navigation method for urban unmanned vehicles, but the magnetic nail spacing is large, and it needs to maintain a high speed. It is not suitable for inspection robots, and it is very dependent on the creation of curvature maps.

SONG Z and others[3]realized the inertial navigation of AGV based on Kalman filter and magnetic nail, but in essence it is still dead reckoning navigation. Magnetic nail is only used for positioning rather than full navigation.

Yuan Mingxin[4]and others designed a magnetic nail detection device and magnetic navigation control algorithm for outdoor inspection robots. Firstly, according to the needs of robot magnetic navigation in outdoor environment, the magnetic nail selection and arrangement are carried out. Then design and manufacture the magnetic nail detection device ; then, the magnetic field ratio function is constructed for the magnetic field distribution of the magnetic nail, and the transverse deviation of the magnetic nail is determined. Finally, the precise magnetic navigation of outdoor inspection robot is completed according to the designed variable parameter PID controller.

In conclusion, the characteristics of magnetic navigation AGV, such as fixed route, inflexible change and insufficient flexibility, make it difficult to adapt to the intelligent manufacturing scene with high demand for production line flexibility. Therefore, it is difficult to apply magnetic navigation technology to epidemic prevention and control robots such as inspection and distribution.

2.2 Inertial Navigation

Inertial navigation system (INS) is an autonomous navigation system which uses inertial sensors, datum direction and initial position information to determine the position, direction and speed of the carrier in the inertial space. Inertial navigation includes inertial measurement unit (IMU) and calculation unit. The change information of object direction and attitude is perceived by IMU, and then more accurate information is obtained through various conversion and compensation calculations. For example, the initial position, initial orientation, initial attitude of the object, and the change of orientation and angle at each moment in the following are detected, and then these information is added to continuously calculate the current orientation and position of the object.

In general, due to the error accumulation of inertial navigation system and the premise requirements for initial calibration, it can not be used alone and can only be used as an auxiliary for other main positioning navigation technologies (such as GNSS positioning, UWB positioning, WLAN positioning, geomagnetic positioning, etc.).

Wang Daolei[5]and others proposed an omnidirectional mobile platform based on optical flow sensors and inertial navigation. The pose information is obtained by optical flow sensor and inertial navigation. In terms of structure and control, the structure of omnidirectional mobile platform of four-wheel Mecanum wheel and its pose calculation are studied, and the double closed loop PID control law of vehicle angle and pose is analyzed. Through Simulink simulation, the upper computer is established to obtain sensor data in real time. The data changes of each sensor under different conditions and the parameter adjustment of double closed-loop control are studied to find the best control parameters.

Yang Shuai[6]proposed a fire robot positioning system based on inertial navigation and ZigBee. Through the robot pose update algorithm, the position and attitude data of the robot are obtained in real time by using the strapdown inertial navigation system. The TOA ranging principle of the ZigBee positioning system is used to realize the robot positioning. The fusion of the two positioning systems is realized by combining the positioning strategy. The error correction of the positioning system is realized by the extended Kalman filter algorithm.

2.3 Visual Navigation

The mobile robot vision technology is to configure the visual device for the robot, collect the environmental image information through the camera, process the collected information, and convert it into the map data that can be used by the computer. Then, the data are integrated and analyzed, and finally a suitable path for the robot to reach the destination is planned through the calculation with certain constraints. The following figure is the key technology of visual navigation.

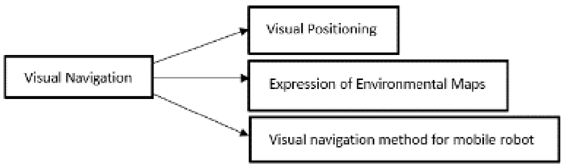

Figure 1 Key Technologies of Visual Navigation

2.3.1 Visual Positioning

Visual positioning refers to the perception of the surrounding environment information through the fixed visual sensor on the mobile robot, and then the environmental feature information is extracted through a series of filtering noise reduction processing. Finally, the pose of the mobile robot is calculated through image processing technology and machine vision technology. There are two main positioning methods based on environment model : relative positioning and absolute positioning[5]. Compared with laser and infrared ultrasonic sensors, visual sensors have the characteristics of low price, high precision and rich information.

Relative positioning method, also known as dead reckoning, is usually known as the initial pose. By calculating the relative pose between two adjacent frames, the pose of the next frame is estimated from the previous frame, and then the whole trajectory is calculated. Absolute positioning method is also called global positioning. This method does not require to know the initial pose of the robot and can determine the pose of the robot at any time. The surrounding environment information is collected through the camera and the environmental characteristics are extracted.

2.3.2 Expression of Environ-mental Maps

At present, in view of the actual situation, the maps in navigation are mainly divided into grid maps, geometric maps, topological maps and hybrid maps that integrate the advantages of several maps.

2.3.2.1 Grid Map

At present, the most widely used path planning algorithm based on raster map is proposed by Elfes and Moravec[7-8]. Grid map regards the environment as multiple grids on the plane. Through the binary information carried by each grid, it can characterize whether the space area is a feasible area or an obstacle area[13], so as to form the obstacle information of the whole environment, and provide the basis for subsequent path planning.

2.3.2.2 Feature Map

Geometric maps are used to fit the obstacle information through common geometric features, such as common point features, linear features, and plane features to build the main environmental framework of the environment. Therefore, it is necessary to know the specific position of these features in the environment[9]. Positioning based on geometric map is to measure the environmental data observed by the camera and compare it with the built environmental framework. The specific position of the robot in the environment is determined by feature estimation technology to achieve positioning[10].

2.3.2.3 Topological Map

The concept of using topological structure to represent the environment map for mobile robot navigation and positioning was first proposed by Mataric & Kuipers[11]. The topology graph describes the environment by many key nodes and lines connecting these nodes, which can vividly represent thetopological structure of the environment.

2.3.2.4 Hybrid Map

The mixed map mainly includes three forms : grid-geometric map, geometric-topological map and grid-topological map. Hybrid map is usually considered to select the most suitable map in specific scenarios, which is usually applied to environmental representation in large scenarios. Compared with single map mode, hybrid map is more flexible, accurate and robust[9].

2.3.3 Visual navigation method for mobile robot

Vision-based indoor navigation technology is to capture the surrounding environment information through the camera, and then plan a feasible path through the identification of surrounding obstacles and non-obstacles, so as to realize the autonomous navigation of mobile robots. Common visual navigation methods for mobile robots include map model matching based on environmental information, synchronous positioning and map construction,and map-independent navigation.

2.3.3.1 Map Model Matching Based on Environmental Information

The working environment features are extracted and processed before navigation, and the global map is established. The map is stored in the database of the robot, and the map is called for matching and positioning in the navigation process. The image features or landmarks captured by the camera are compared with the map in the library to calculate the probability of matching, and then determine the pose of the robot, and plan the appropriate path through the planning module. The navigation technology process can be divided into the following steps[12]:

(1) Image acquisition : camera captures video images of the surrounding environment ;

(2) Road sign recognition and detection : preprocessing the collected image through image processing technology ;

(3) Road sign matching : matching the captured image with the image in the library ;

(4) Position calculation : When matched with the features or landmarks in the library, the system calculates the pose of the robot in the environment according to the information in the library. There are two typical map matching methods[9] : 1) The starting point and map are known. This situation is the simplest and belongs to local positioning. 2) Unknown starting point, known map. Belongs to global positioning, generally will introduce some auxiliary methods, common auxiliary methods include adding artificial beacon, infrared or ultrasonic system for auxiliary positioning.

The literature[13]uses a matching method based on complete lines and feature points. The global map of the environment is composed of directed segment features and point features, and the matching is based on the relative position relationship between feature points and directed segment. In order to solve the navigation problem when the scene is large and the map is known, Zheng Hong[14]and others developed a navigation control system composed of map editing, map matching and positioning module and multi-level hierarchical planning module. The feasibility of the system is verified by experiments. Qiu Shubo[15]and others realized AGV autonomous navigation by electronic map auxiliary camera to identify the ground marking line. The precise positioning of the system is realized by inputting two parameters of the ground marking line and the identifier with known absolute coordinates in the electronic map. Experiments show that the scheme has good tracking effect for straight lines and curves, and the azimuth deviation and lateral deviation can well meet the actual needs.

2.3.3.2 Synchronous positioning and map construction

SLAM (Simultaneous Localization and Map Building) technology is proposed by Smith[16]et al. It is a research hotspot of mobile robot. SLAM technology refers to the mobile robot does not know its position in the environment, through the camera constantly observe the environment, incrementally build a complete environment map.

Henry P et al.[17]first used RGBD camera to reconstruct the indoor environment. The motion transformation of the robot is calculated by calculating the SIFT operator in the image, combining with the depth image and RANSAN method, and then the precise pose is further calculated. An improved SLAM algorithm based on beacon recognition and binocular vision is proposed in the literature[18]. The stereo image information is collected by binocular camera, and the visual beacon is detected and the ORB feature points are extracted. The initial value of camera pose is calculated according to the beacon positioning information and the feature point matching information. The local pose optimization and global optimization are carried out based on the graph optimization framework, and the map points and key frame data are maintained, so as to achieve high precision positioning and map construction. The experiment shows that the error is controlled within 5 cm.

The literature[19]locates itself through dense image alignment, and constructs a dense 3D map. The literature[20]pointed out three key issues in visual SLAM : feature detection and matching, selection of key frames, closed-loop detection method, and advantages and disadvantages of monocular, binocular and RGBD camera SLAM schemes. Mur-Artal et al.[21]proposed an ORB-SLAM method that can realize indoor SLAM. This method extracts key frames of images for registration, and can quickly and efficiently retrieve and match. In view of the shortcomings of low uniformity and long time-consuming of the feature points distribution of ORB-SLAM algorithm in traditional visual navigation technology, the scale pyramid was constructed, the region of interest was set, and the non-maximum suppression method was introduced. Experiments show that when the expected value of feature points is 3000, the distribution uniformity of feature points increases by 71.13 %, and the time-consuming reduction ratio is 69.52.

2.3.3.3 Not dependent on map navigation

This method does not need to build environmental maps, commonly used in obstacle avoidance. The robot ' s activity depends on the environmental obstacles captured by the camera at the time, without having to define the absolute coordinates of the obstacles. Usually divided into three categories[15]: navigation technology based on optical flow, navigation technology based on appearance information, navigation technology based on target recognition and navigation technology based on target tracking.

3. DEVELOPMENT TREND AND PROSPECT OF VISUAL NAVIGATION TECHNOLOGY

The visual navigation technology of mobile robot is a rapidly developed and mature technology, and it is also a manifestation of the intelligent mobile robot. After summarizing some common visual navigation schemes for mobile robots, three kinds of navigation methods are also reviewed. However, mobile robots still have huge development space. The current visual navigation technology usually needs to be completed in specific situations, but it cannot be well solved in real and complex environments. How to make the visual navigation scheme adapt to different complex environments remains to be solved. In addition, light has a great impact on the visual effect, and how to reduce the impact of environmental factors on the scheme in image processing. Secondly, in the process of visual navigation, we need to identify a large number of environmental information, and also need to process and calculate a large number of data. Therefore, efficient computing speed and sufficient running memory are the premise of large environment visual navigation. With the continuous updating of technology, the visual navigation technology of mobile robot will move towards the direction of more accurate positioning, more optimized path and more reasonable memory occupation.

With the change of epidemic prevention and control needs, the needs of mobile robots will also change. As the current mainstream mobile robot navigation technology, SLAM technology is believed to shine brilliantly in the field of mobile robot navigation technology and win the battle against this epidemic!

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